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Hydropower use in Pakistan: Past, present and future

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Abstract

Energy is an essential ingredient of socio-economic development and economic growth. Electricity is a basic part of nature and it is one of the most widely used forms of energy. Hydropower is perceived as an environment-friendly, low-cost source of electricity that relies on proven technology. Pakistan has been an energy-deficient country historically. The installed electricity generation capacity is 19,547 MW presently out of which 6599 MW comes from hydropower. The identified hydropower potential in the country is approximately 41,722 MW. The Government is accordingly giving priority to hydropower generation projects in both public and private sectors. Recent power policies have attracted good response from private entrepreneurs. Several projects are in different stages of implementation. Micro-hydropower development in the northern part of the country is benefiting the previously under-privileged communities. This article presents an overview of hydropower development in Pakistan.

Keywords: Hydropower; Renewable energy; Pakistan

Contents

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1. Introduction

1.1. Energy and electricity

Energy is of little interest for its own sake. It is, however, an essential ingredient of socio-economic development and economic growth. Moreover, the production and consumption of energy is often linked to other major issues in society, including poverty, environmental degradation, and security challenges [1].

Electricity is a basic part of nature and it is one of the most widely used form of energy. It is a secondary energy source, obtained from the conversion of primary sources of energy, like coal, natural gas, oil, nuclear power and other natural sources. The provision of reliable and affordable electricity is essential for improving public health, providing modern information and education services and saving people from subsistence tasks, such as gathering fuel. Historically, economic growth has been highly correlated with electricity use.

The global electricity production has more than doubled over the past 22 years, though access is highly skewed between and within countries. Almost 2 billion people, both urban and rural poor, have no access to electricity at all [2].

1.2. Hydropower

Hydropower has been perceived and promoted as a comparatively clean, low-cost, renewable source of energy that relies on proven technology. Except for reservoir evaporation, it is a non-consumptive use of water. Once built, hydropower, like all renewable sources, is considered to have low operating costs and a long life, particularly run-of-river projects and reservoir projects where sedimentation is no concern. In the past, hydropower was especially attractive to governments with limited fossil fuel resources, who would otherwise have had to import fossil fuels to sustain power generation. At a global scale, current levels of hydropower generation offset 4.4 million barrels of oil-equivalent (thermal electric generation) a day, roughly 6% of the world's oil production [2].

Hydropower projects have inherent ability for instantaneous starting, stopping, load variation, etc. and help in improving reliability of power system. Hydropower projects are best choice for meeting the peak demand. The generation cost is not only inflation free but reduces with time. In the USA, hydropower is produced for an average of 0.85 cents per

kilowatt-hour (kWh). This is about 50% the cost of nuclear, 40% the cost of fossil fuel, and 25% the cost of using natural gas. In the year 2000–2001, the average cost of hydropower generation in Pakistan was about Rs. 0.20 per kWh. Hydropower projects also help in opening of avenues for development of remote and backward areas [3–5].

Hydropower currently provides 19% of the world's total electricity supply and is used in over 150 countries. About a third of the countries in the world currently rely on hydropower for more than half of their electricity needs. Norway produces more than 99% of its electricity with hydropower. New Zealand uses hydropower for 75% of its electricity. Hydropower is the leading source of renewable energy. It provides more than 97% of all electricity generated by renewable sources worldwide [2,4].

This article presents an overview of hydropower resource development in Pakistan.

2. Energy and electricity situation in Pakistan

Pakistan has been an energy-deficient country historically. Total Primary Energy Supply (TPES) per capita is far below the world average and only a small faction of that for OECD region and other developed countries, as shown in Fig. 1.

When Pakistan got independence in 1947, it inherited only 60 MW generation capacity for its 31.5 million people. The pace of electric power infrastructure development gained momentum by the year 1970 and within 5 years the installed capacity rose from 636 MW in 1970 to 1331 MW in 1975, with setting up of a number of hydro and thermal power units. In the year 1980, the system capacity touched 3000 MW and thereafter it rapidly grew to over 7000 MW in 1990–1991 [7].

During the last decade and a half, the installed capacity has more than doubled, with both thermal and hydropower playing their part (Fig. 2). The electricity generation capacity in the country has risen to 19,547 MW now, out of which 7707 MW is through Independent Power Producers (Table 1). The addition of 1450 MW capacity during 2001–2005 through the Ghazi Brotha hydropower project has resulted in change in the hydro/thermal ratio from 0.40 in 2001 to 0.53 in 2006.

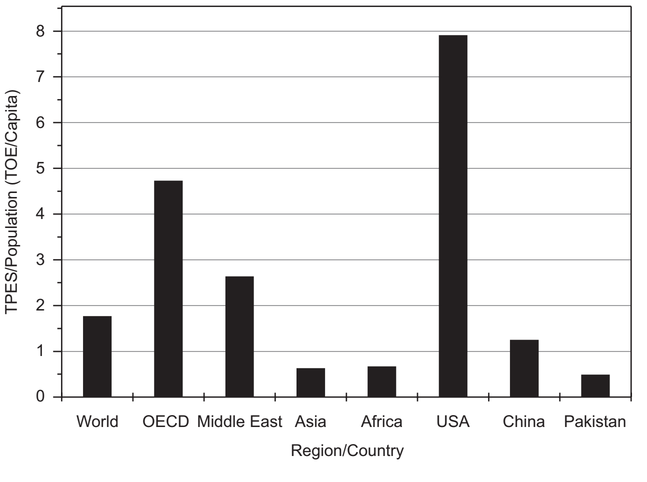


Fig. 1. A comparison of TPES per capita between Pakistan and other regions/countries [6].

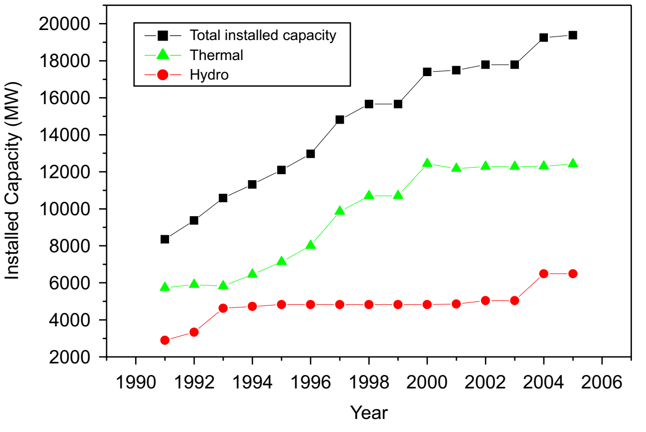


Fig. 2. Growth of electric power installed capacity in Pakistan during last 15 years [7].

Table 1
Installed electricity generation capacity (MW) in Pakistan [3]

Sector	Thermal	Hydro	Nuclear	Coal	Total
Public sector	4629	6599	462	150	11,840
Private (IPPs)	7707	—	—	—	7707
Total	12,336	6599	462	150	19,547

Despite all this progress, the per capita electricity consumption stands at 469 kWh per capita, which is less than one-fifth of the world average (2465 kWh per capita) and just about 5% of the consumption in the OECD countries [8]. Provision of cheap hydropower can certainly play a role in reducing this gap.

2.1. *Future electricity demand*

The electricity demand is projected to grow with an annual compound growth rate (ACGR) of 7.9% during the Medium Term Development Framework 2005–2010 of the Government of Pakistan, and increase from 15,500 MW in 2005 to 21,500 MW in 2010 [9], as shown in Fig. 3.

3. Hydropower development in Pakistan

At the time of independence in 1947, the installed hydropower capacity was only 10.70 MW which comprised a 9.6 MW station at Malakand in North-West Frontier Province (NWFP) and a 1.1 MW one at Renala in Punjab. With the implementation of the Indus Water Treaty of 1960, Pakistan embarked on the construction of two giant earth-rock dams at Mangla and Tarbela [7,10]. Mangla and Tarbela power stations, with 1000 and 3478 MW installed capacities, were the largest contributors to hydropower generation before Ghazi Barotha (1450 MW) came online in 2004. The growth of hydropower generation capacity is graphically shown in Fig. 4.

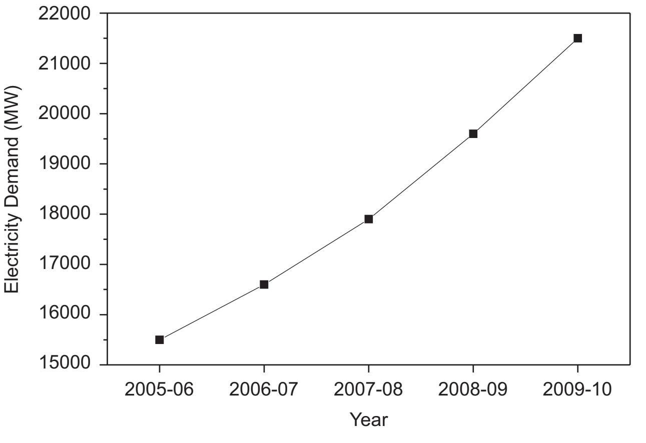


Fig. 3. Electric power demand projections up to 2009–2010.

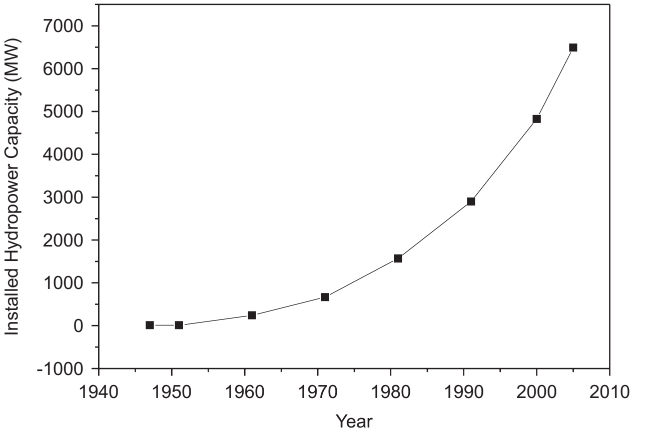


Fig. 4. Growth of hydropower installed capacity in Pakistan [7,11].

Table 2
Major hydropower generation units in Pakistan

Project	Location	Installed capacity (MW)	Type
Tarbela	NWFP	3478	Reservoir
Ghazi Barotha	Punjab	1450	Run-of-river
Mangla	AJK	1000	Reservoir
Warsak	NWFP	240	Reservoir
Chashma	Punjab	184	Reservoir

In Pakistan, the hydropower resources are mainly in the north; the resources in the south being scarce. The total installed capacity of the hydropower stations in the country is about 6599 MW, out of which 3767 MW is in NWFP, 1698 MW in Punjab, 1036 MW in Azad Jammu & Kashmir (AJK) and 93 MW in the Northern Areas [12]. Table 2 shows a list of existing major hydropower plants in Pakistan; the respective locations are shown in Fig. 5.



Fig. 5. Locations of major hydropower projects (courtesy of Federation of American Scientists, http://fas.org/nuke/guide/pakistan/facility/pakistan-map.gif).

3.1. Organizational/institutional infrastructure

A brief introduction of the organizations/institutions involved in hydropower development in Pakistan is given below as follows [12–15].

The Ministry of Water and Power. It plays the lead role in implementation of all policies pertaining to water and power issues in the country.

Water and Power Development Authority (WAPDA). WAPDA was established in 1958 and entrusted with a massive agenda, including generation, transmission and distribution of electrical power together with irrigation, water supply, drainage and flood control, etc. It owns about 54% of the country's total electrical power generation capacity, and serves 88% of all electricity customers of Pakistan. In 2001, WAPDA announced an ambitious plan, Vision 2025, to develop Pakistan's water and hydropower resources. The plan is to be implemented in three phases. A total of 23 hydropower projects would be completed by 2025 under this plan.

Private Power and Infrastructure Board (PPIB). PPIB was established by the Government of Pakistan in 1994 as an extension of the Ministry of Water and Power, for encouraging participation of private entrepreneurs in the power generation.

Karachi Electric Supply Corporation (KESC). KESC was established in 1913 and is one of the oldest utilities in the South Asian region. It caters for the electric power

requirements of Karachi. KESC is principally engaged in the generation, transmission and distribution of electricity to industrial and other consumers within its licensed areas.

National Electric Power Regulatory Authority (NEPRA). NEPRA was established under the Regulation of Generation, Transmission and Distribution of Electric Power Act 1997. The main functions of NEPRA are to grant licenses for generation, transmission and distribution of electric power, prescribe and enforce performance standards for generation, transmission and distribution companies, and determine tariff, rate etc. for the supply of electric power services. Being a regulator, NEPRA is responsible for all matters related to the tariff of electric power in the country.

Energy Wing—Planning and Development Division. The Energy Wing was created in 1988 under the Ministry of Planning and Development to undertake technical, financial and economic appraisal of generation, transmission and distribution projects submitted by WAPDA, KESC, etc. The Energy Wing also prepares short- and long-term energy sector programs, including forecasts on supply and demand of utilities.

Sarhad Hydel Development Organization (SHYDO). In 1986, the Government of NWFP established SHYDO for carrying out hydropower prospects, hydropower development and to act as a utility company for the isolated rural communities. With the assistance of WAPDA and German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit, GTZ), SHYDO has prepared a master plan for the development of more than 6000 MW hydropower potential identified in NWFP. It has successfully completed feasibility studies of several hydropower projects ranging from 8 to 125 MW. Presently, SHYDO is implementing 81 MW Malkand-III hydropower project.

Punjab Power Development Board (PPDB). PPDB was created in Punjab's Irrigation Department in 1995 for the promotion of hydropower generation on canal sites in Punjab. At different canals, about 324 potential sites of medium and low head were identified, with a total estimated capacity of 5895 MW.

Irrigation Power Department Sindh (IPDS). IPDS is responsible for the hydropower development and identification of suitable sites on canals and barrages in Sindh.

AJK Hydro Electric Board (AJK HEB) and AJK Private Power Cell (AJK PPC). In order to exploit the plentiful hydropower resources of AJK, the Government of AJK established the AJK HEB in 1989. Subsequently, with the intention of providing a one-window facility and to encourage the development of hydropower potential in the private sector, AJK PPC was created in 1995. AJK HEB and AJK PPC are implementing many hydropower projects in public and private sector.

Northern Areas Public Works Department (NAPWD). To provide electric power to the isolated network of the Northern Areas, the NAPWD was established, which is responsible for the generation and distribution of electricity. NAPWD has constructed various mini hydropower stations in the region, and has built 11 kV lines for the transmission of electric power to consumers. Currently, approximately 40% of the local population of Northern Areas has been provided electricity.

Pakistan Council for Renewable Energy Technologies (PCRET). PCRET was created in 2001 by merging National Institute of Silicon Technology (NIST) and Pakistan Council for Appropriate Technologies (PCAT). PCRET has been assigned the responsibility to coordinate research and development activities on renewable energy technologies in the country, particularly in the areas of micro-hydropower plants, biogas, fuel-saving technologies, solar thermal appliances, photovoltaics and wind energy.

Alternative Energy Development Board (AEDB). The Government of Pakistan created the AEDB in May 2003 to act as the central national body on the subject of renewable energy. The main objective of the Board is to facilitate, promote and encourage development of renewable energy in Pakistan with a mission to introduce alternative/renewable energy at an accelerated rate to achieve 10% share of renewable energy in the energy mix of the country by 2015.

3.2. Electric power generation policies

Due to the inability of WAPDA to install new power projects to cater to the electricity demand during the 1980s, the country ended up in severe power crises, resulting in long-lasting load shedding and a huge loss to the Government revenues. In order to overcome these problems, in 1985, the Government of Pakistan announced certain incentives to encourage private investment in the power sector. In 1993, the Government planned a rapid increase of generating capacity and offered additional incentives for private investment in the power generation. Power policies announced by the Government from time to time are briefly described below here [12]. Details can be found at PPIB web site http://www.ppib.gov.pk.

1994 Power Policy. In March 1994, the Government announced the "Policy Framework and Package of Incentives for Private Sector Power Generation Projects in Pakistan". This policy attracted an enthusiastic response, mainly in thermal power plants, and resulted in direct foreign investment of US$ 4 billion.

1995 Hydel Power Policy. In May 1995, the Government announced the "Policy Framework and Package of Incentives for Private Sector Hydel Power Generation Projects in Pakistan", with an emphasis on promotion of hydropower generation. Like the 1994 Power Policy, the Hydel Policy 1995 also elicited an encouraging response. Forty-one Letters of Interest and 13 Letters of Support were issued under its provisions.

1998 Power Policy. In July 1998, the Government announced its "Policy for New Private Independent Power Projects". This policy was based on the concept of minimum levelized tariff through international competitive bidding. However, the response from the private sector was not encouraging.

2002 Power Policy. In October 2002, the Government announced its "Policy for Power Generation Projects Year 2002". This policy 2002 envisages implementation of both solicited and unsolicited proposals. Response is encouraging and 23 proposals have been received so far, out of which five are for the hydropower projects with an estimated capacity of 1074 MW.

4. Identified hydropower potential in Pakistan

Pakistan is blessed with approximately 41,722 MW of hydropower potential, most of which lies in NWFP, Northern Areas, Azad Jammu & Kashmir and Punjab. So far only about 15% of this potential has been harnessed and 8–10% is under various stages of development. Thus, around 75% of the potential remains un-exploited. Table 3 presents the details of hydropower potential identified in various regions of Pakistan [3,12].

Many other sources describe hydropower potential between 30,000 and 50,000 MW [9,11,16–19].

Table 3
Summary of the hydropower potential in various regions of Pakistan

Region	Projects in operation (MW)	Public sector projects (MW)	Private sector projects (MW)	Projects with feasibility study (MW)		Projects with pre-feasibility study/ raw sites (MW)	
				Above 50 MW	Below 50 MW	Above 50 MW	Below 50 MW
NWFP	3767.2	635.0	84.0	58.0	143.0	13584.0	426.0
Punjab	1698.0	96.0	0.0	3720.0	32.2	0.0	349.7
AJK	1036.1	973.8	828.7	420.0	48.2	1152.0	177.0
Northern areas	93.7	18.0	0.0	505.0	71.5	10905.0	814.0
Sindh	0.0	0.0	0.0	0.0	49.5	80.0	48.6
Balochistan	0.0	0.0	0.0	0.0	0.5	0.0	0.0

5. Present activities

The optimal utilization of hydropower potential is accorded priority in the power development program under MTDF. Several public sector projects including Allai Khwar (121 MW), Khan Khwar (72 MW), Dubair Khwar (130 MW), Golan Gol (106 MW), Malakand-III (81 MW), and Keyal Khwar (130MW) in NWFP and Jinnah low head (96 MW) in Punjab, are at different stages of implementation. New Bong Escape (79 MW) and Rajdhani (132 MW) in AJK are being implemented in private sector. In addition, Battar (4.8 MW) in AJK and Naltar-III (18 MW) in Northern Areas have also been approved for implementation under the provincial program. Additional electricity from Mangla Dam would also become available after the ongoing project to raise its height. Tendering process is underway for construction of Neelum Jhelum (969 MW). Feasibility study of Basha Diamer Dam project is expected to be completed in 2006. This project will have 3660 MW installed capacity. Recently, PPIB has invited proposals for the 960 MW Tarbela 4th Extension Hydropower Project [3,9,12,13].

6. Future plans

On February 15, 2005, the President and Prime Minister of Pakistan approved the Energy Security Action Plan to meet growing energy requirements in immediate, medium- and long-term perspectives [20,21]. Its major objective is to enhance the power generation by harnessing more indigenous resource-based generation like hydro, coal and gas, etc. In order to improve the hydro–thermal mix towards hydro as well as to augment the existing water storage facilities, hydropower projects are being given preference. Feasibility and detailed engineering work on major hydropower projects is already underway and their construction would be initiated during the MTDF. The feasibility studies for additional hydropower potential would also be pursued in public/private sector.

To meet the future load requirement, an additional 7100 MW of power would be installed by 2010. A total of 22 projects, including 12 hydropower based, would be completed during this period. The power generation plan up to 2030 is presented in Fig. 6.

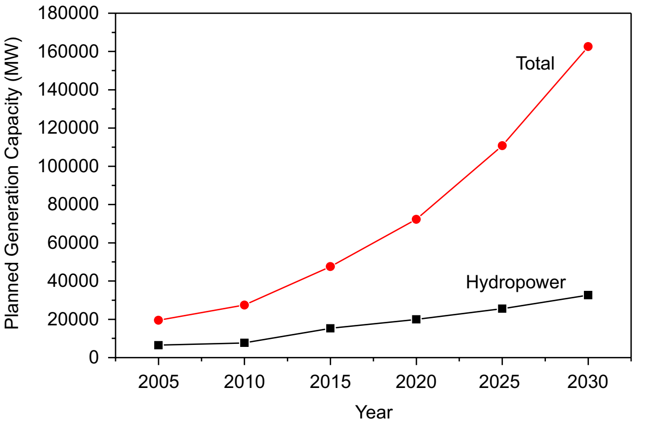


Fig. 6. A pictorial representation of power generation plan up to 2030 [9].

7. Micro-hydropower development

The northern part of the country is rich with hydropower resources. Other than 12 big (capacity greater than 1 MW) hydropower plants, there are a large number of sites in the high terrain, where natural and manageable waterfalls are abundantly available. The population in these areas is isolated in thin clusters and is located far from physical infrastructure. Such remote population can get great benefit from such energy sources [22].

The recoverable potential in micro-hydropower up to 100 kW is roughly estimated to be 300 MW on perennial water falls in northern Pakistan. Besides, there is an immense potential for exploiting water falls in the canal network particularly in Punjab, where low head high discharge exists on many canals. More than 300 such locations with nearly 350 MW potential have been identified so far [23].

PCRET and/or its predecessor organization PCAT have co-financed installation of a total of some 300 run-of-river type plants with total capacity of 4 MW. With the assistance of Asian Development Bank, 100 micro-hydropower plants with ratings ranging from 5 to 50 kW are being installed in and around Malakand in NWFP. A pilot project for development and installation of two 40 kW micro hydro turbines has been undertaken by AEDB [18,23].

8. Conclusions

Hydropower is renewable with a proven track record and technology. No fuel is needed and operation and maintenance costs are low. It has many environmental benefits as well; hardly any atmospheric pollutants are emitted in hydropower generation. Micro-hydropower is beneficial to the off-grid small communities, improving their living standard.

Pakistan has undoubtedly enormous potential for hydropower, only a small portion of which has been exploited so far. Development of indigenous hydropower resources will decrease reliance on imported oil, thus enhancing energy security and at the same time reducing oil import bill. The Government has been making concerted efforts to increase hydropower generation capacity in the country and recent policies reflect that.

Acknowledgments

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